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RESERVE STOCKS OF GRAIN: A REVIEW OF RESEARCH LITERATURE

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COMMODITY
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ECONOMIC RESEARCH SERVICE   U.S. DEPARTMENT OF AGRICULTURE

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Summary

The recent interest in reserve stocks can probably be explained by two factors: (a) current low stocks of grains and oilseeds around the world, and (b) changing world conditions which appear to dictate that the U.S. grains market will have volatile prices in the future unless policy measures are used to moderate those conditions. Should the U.S. have a reserves stock policy? If so, what kind. Research is needed to help answer these questions. The purpose of this paper is to review previous research and theory related to reserve stocks accumulation and to give some direction to the current round of research.

The literature reviewed gave valuable insights into model building and theory, but because of the recent rapid structural change taking place in U.S. and world markets, most had out-of-date results. Current estimates are needed. New models can incorporate the strengths of the old and include changes in data and model structure consistent with changes in real world market structure.

In this paper each major component of reserve stocks analysis was reviewed. They were (a) the overall objectives to be achieved, (b) the types of storage rules used to achieve the objectives, (c) the market conditions modeled, and (d) the evaluation of the effectiveness of storage rules achieving specific objectives. Major conclusions reached from the review are:

1. There is no one optimal stocks policy. There are many objectives that might be achieved by holding reserve stocks and for each objective there might be an optimal stocks policy. In reality, society will eventually want to achieve multiple objectives, making the search for an optimal stocks policy even more difficult.

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1. There is no one optimal stocks policy. There are many objectives that might be achieved by holding reserve stocks and for each objective there might be an optimal stocks policy. In reality, sectors will eventually want to achieve multiple objectives, making the search for an optimal stocks policy even more difficult.

2. In future models built to analyze alternative reserve stocks policies, the demand portion will need to incorporate a more thorough demand-for-U.S.-exports component. Shifts over time in the short-run demand function should also be included to allow for growth in demand.
3. The authors analyzed grain reserve policies for one commodity or one group of commodities. Future studies should include an examination of the substitutability in demand of all food and feed grains and oilseeds. When supplies are short how widely will grains substitute for each other? What are the implications for the size of reserve stocks for each grain?
4. In past studies, supply was primarily a function of stochastic yields. The next round of studies should also define supply as a function of planted acres, where acreage responds to market conditions and public farm programs.
5. A major issue needing evaluation in future stocks models is, "given the various objectives for having reserve stocks, does it make any difference who controls the stocks?" What does economic theory have to say on this issue? Does public control lead to greater social well-being? If there were no public reserve stocks, would the private sector hold a socially desirable level of stocks? Can public control be separated from political manipulation? Some of these questions are able to be researched and should be addressed in future reserve stocks models.

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RESERVE STOCKS OF GRAIN: A REVIEW OF RESEARCH

I. Introduction

There is much concern with the recent low levels of U.S. grain and soybean stocks. The following table shows that during the 1954-1962 period stocks were high relative to prior years, except for soybeans. During the 1950's, stocks were accumulated as a byproduct of the price support programs. The accumulated stocks were drawn upon during the Korean Conflict, the unusual world need in 1966 and by the corn blight and foreign demand during the early 1970's. By the end of the 1973 crop year wheat and rice stocks will be below 10 percent of 1973 utilization and feed grain stocks will be only 12 percent. Soybean stocks are expected to be up after the tight situation prior to the harvest of the 1973 crop.

World conditions affecting food are very volatile so that small changes in these conditions could cause major market reactions in the U.S. Cochrane [2] lists these factors as (a) nearly half of the world being near starvation, (b) demand for grain being highly inelastic, (c) demand for meat abroad being inelastic, and (d) reserve stocks of grain abroad being very small. The U.S. could dampen the volatile market impact of these factors with reserve stocks.

Because of current low stock levels and because of world conditions, there is renewed interest in establishing new national and/or international policy on reserve stocks. The subject has come up in numerous speeches by U.S. and U.N. policy people.

Beginning stocks as a percentage of annual utilization, U.S.

	Wheat	Rice	Feed Grains	Soybeans
1935-1953	31	5	17	2
1954-1962	102	32	43	3
1974	10	5	12	16

Source: 1935-1962 [9], 1974 [18].

The purpose of this report is to review the literature on research and theory related to U.S. accumulation of reserve stocks[1/] of grain and soybeans. Speeches, a review of past stock policies, and management techniques for handling day-to-day problems of purchase and sale of stocks will not be covered here.[2/] This review is to serve as a basis for continuing research on reserve stocks.

This review consists of three parts. First, the basic components of stocks analysis are presented. Second, three models are reviewed that contain all the basic components. And third, conclusions are drawn about the present state of the research arts in the area of reserve stocks analysis, and suggestions are made for future research.

II. Basic Components of Reserve Stocks Analysis

Any analysis of reserve stocks should implicitly or explicitly include four components; (a) the overall objectives to be achieved, (b) the types of

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[1/] In this review the term "reserve stocks" refers to working stocks plus any additional stocks held under public or private control at the end of a crop year just prior to harvest.

[2/] The reader will find a current review of historical policy approaches to stocks management in Bailey, et al [1] and a discussion of alternative grain reserve policies in Steele [15].

storage rules that will be used to achieve the objective, (c) the specification of the market conditions, e.g., supply, demand, the role of government, etc., and (d) a method for evaluating the effectiveness of storage rules in achieving specific objectives. The literature contains comments on each of these components.

The Objectives

Waugh [20] observed that society had seven reasons for maintaining a reserve stock of grain.

1. Provide working stocks.
2. Reduce danger of food shortages at home and abroad.
3. Help maintain commercial exports--i.e., a dependable and steady supply.
4. Help stabilize farmers' incomes and the general economy.
5. Along with production adjustment, to raise the level of farm prices and income.
6. Assist growth of underdeveloped areas of the world (LDC's).
7. Foster private industry.

McMinimy and Kutish [9] said that the first and seventh reasons would be achieved by any stocks policy. They then ranked the remaining five in order of importance to them; 1-reduce food shortage danger, 2-stabilize income, 3-maintain exports, 4-raise prices, and 5-assist growth in LDC's. The rank-order of importance put on the above aims helps define the objective functions for stocks research and policy.

More recently a task force of the Council for Agricultural Science and Technology put together a list of six "benefits of a conscious reserve stocks policy" [16]:

1. Protect producers from unstable markets.
2. Protect consumers from unstable markets.
3. Enhance the commercial export market.
4. It may be a less expensive reserve than land retirement and more readily available to utilize.
5. It meets a moral obligation to developing countries.
6. It is an important foreign policy bargaining tool.

The above general reasons for society's concern for reserve stocks provide guidelines for defining specific policy and research objectives. Ideally, these objectives are measurable and one can observe in the real world and in the economic model whether progress is being made in achieving the objectives. Four of the more common objectives are reviewed here.

Target Quantities of Stocks

One of the most familiar objectives discussed in the literature is to maintain a target level of reserve stocks. Three examples in the research literature are Wells and Fox [21], the NAAC study [14], and Waugh [20]. They suggested the following target levels of reserve stocks:

	Wells & Fox 1952	NAAC 1964	Waugh 1967
Wheat--------------mil. bu.	450-500	630	550-650
Cotton-------------mil. bales	4.5-5.0	6.2	5.0-6.0
Feed Grains--------mil. tons	25-28 1/	45	35-45
Rice---------------mil. cwt.	---	9	10-12
Soybeans-----------mil. bu.	---	100	---

1/ Corn only.

Source: Waugh [20].

Wells and Fox based their targets on variations in U.S. crop yields during a 50-year period. They sought a stock level that was adequate to offset a year with very low yields followed by a year with moderately low yields. The NAAC study was especially concerned with national security and increased world needs. Waugh's target stocks were based upon variations in yields, acreage, and demand "supplemented by the judgement of several economists" [20, p. 52].

The suggested target levels were meant by the authors to be rule-of-thumb estimates of the magnitude of U.S. stocks needed to provide reasonable market stability and (where cost was analyzed) at reasonable cost. They are relevant to the supply and demand conditions at the time of the studies. They do not, however, address the issue of how to use the targets once they are defined. As Gustafson points out, this target-level approach "is necessarily an inadequate solution to the storage problem" [4, p. 6]. He points out that an administrator of such a program has no way of knowing if at any given point in time he should be adding to or subtracting from stocks, e.g., if stocks are low and there is a poor crop year, should stocks be increased or decreased?

Stocks Target as a Percent of Trend Production

A modification of the target quantities of stocks is the objective of maintaining a reserve stock that is a percent of the trend production level. Bailey [1] examines various levels of grains stocks from 4 percent to 12 percent of the U.S. production trend. Costs of storage, net accumulation of stocks and the relative ability to overcome world shortfalls in production are examined over an historical period. This objective allows for trends in production and utilization over time but it is still subject to the same criticism as the previous objective.

Reduce Price Variation

Another objective is to reduce price variation over time by putting upper and lower bounds on grains prices. When prices are high stocks are released; when prices are low stocks are purchased. Cochrane [2] recently proposed a reserve stocks program with the objective of maintaining stable U.S. price levels for grains. He suggested, however, that additional policy tools such as supply controls when supplies were short, would be needed as well to help stabilize grain prices. Cochrane warned that it might be politically tempting to use the reserve stocks program not only for stabilizing prices but for holding farm prices permanently above world levels.

Gustafson anticipated the problem of which Cochrane warned. The major weakness of pursueing this objective, Gustafson pointed out, was the problem of properly setting the price bounds. Stocks might either accumulate over time if the price bounds were too high, or always be depleted if the bounds were too low. Future price trends would have to be accurately predicted.

Maximize Social Welfare

There are a series of articles by Waugh [19], Oi [10, 11] and Massel [7] that address the issues of price variability over time along given supply or demand functions. Waugh demonstrates using relative areas under a demand curve that consumers are not better off with price stability as long as the weighted average price over time (given a static demand schedule) is greater than the stabilized price. Oi uses the same logic to show that producers are not better off with price stability. These two ideas were combined by Massell into one model to evaluate the welfare aspects of price stabilization for both consumers and producers. Massell demonstrates by

using the Waugh and Oi concepts in one equilibrium model containing a static demand curve and a randomly shifting supply curve, that there is a net social gain from price stabilization. He then shows graphically and algebraically the gain to be made by storing some quantity during the overproduction year and selling it during the underproduction year.

Samuelson [12, 13], however, points out a basic flaw in the Waugh and Oi interpretation and shows that consumers and producers separately benefit from price stability. He did not mention the Massell article, but Samuelson's argument with the Waugh and Oi papers raise doubt about Massell's interpretation. The disagreements among reputable economists suggests that if the objective of maximizing social welfare (working with consumer and producer surplus) is to be used in a research model, then the conflicts appearing in the literature will have to be resolved.

Gustafson [4] in his model maximizes the total value of production--the integral of the demand function from 0 to the quantity consumed--over time. On the other hand, Tweeten minimizes the net social cost over time. These models are discussed in detail in section III.

Storage Rules

A storage rule defines how reserve stocks will be managed in order to achieve a specified objective.[3/] A storage rule tells a national storage decision-maker (and the general public) precisely how much should be added to or taken from reserve stocks in a given year. Heady [5] emphasizes that a

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[3/] This definition is broader than the definition used by Gustafson [4, p. 2]. He defined a storage rule as the functional relationship between supply and reserve stocks whereas the definition used in this paper includes functional forms where variables other than supply are allowed.

reserve stocks program should be "actuarally (statistically) determined" and "subject to a precist set of rules", i.e., a storage rule should be statistically defined and then used. He also pointed out the necessity of the whole system knowing what the rule was and how it operated.

Five of the more common storage rules stated (or implied) in the literature are discussed here. The questions of who enforces the storage rules, the mechanics of how purchases or sales are made or who does the storing are important but they are not addressed in this paper.

1. Reserve stocks = a constant target quantity. This is a naive storage rule and is discussed only for illustrative purposes. Strictly interpreted, no accumulation or use of stocks is allowed once the target is reached. Loosely interpreted the rule makes little economic sense, because at times it would force stocks to build-up to the target during periods of high prices and shortages or deplete stocks down to the target during periods of low prices, i.e., this storage rule ignores price.
2. Reserve stocks = f(production). Both Waugh [20] and Bailey [1] suggest storage rules where reserve stocks are a function of production. When production is above average or above a trend line, stocks are to be accumulated and when production is below average or below a trend line stocks are to be depleted. This storage rule is defined by stating the functional form of the equation.
3. Reserve stocks = f(price, loan rate, target stocks). Recently McGrory [8] defined a storage rule as a function of price, loan rate and target stocks. His proposal expressed target carryover stocks as a percent of (a) U.S. commercial demand, plus (b) predictable U.S. concessional sales,

plus (c) U.S. food aid. Target carryover stocks in his proposal were food grains--50 percent, feed grains--25 percent, and oilseeds--25 percent. Target carryover stocks include pipeline stocks. The Secretary of Agriculture could use set-aside provisions in conjunction with the loan rate provisions to regulate carryover. The loan rate for soybeans, however, would need to be set at 2.7 times the corn loan rate.

McGrory's proposal set the following storage rules: (a) if stocks fall to 50 percent of target levels, CCC cannot sell stocks for less than 200 percent of loan rates, and (b) if stocks are over 50 percent of target levels, the CCC can sell at the market price if it exceeds 115 percent of the loan rate plus carrying charges.

4. Reserve stocks = f(price). This rule is generally specified in terms of upper and lower price bounds on the commodity to be stored. If the market price drops below the lower bound, stocks are accumulated and if the price exceeds the upper bound stocks are depleted. Tweeten uses this type of storage rule in his model which is discussed in section III.
5. Reserve stocks = f(supply). The storage rule used by Gustafson is to make reserve stocks a function of supply--beginning stocks plus production. The relationship can be rewritten as: Ending reserve stocks = f(stocks carried over from previous year plus production). In general, as supply increases, reserve stocks carried over to next year increase. Estimation of alternative forms of this function are discussed in the review of Gustafson's model in section III.

Market Conditions

Any model used to analyze reserve stocks contains an actual or implied set of market conditions including production or supply, demand (domestic or

export) and storate costs. The model may contain other components related to market conditions such as (a) what discount rate should be used for future expected costs or returns from storage, (b) which variables should be considered stochastic over time and which should be assumed deterministic, (c) is it a free market or is there government intervention, and (d) are market conditions static or dynamic over time.

Supply and Demand

The pre-1960 studies generally assumed that demand for individual crops was either static or shifted at a steady and predictable rate. The demand for U.S. exports of grains was relatively minor. The justification for reserve stocks rested upon the more unpredictable supply function--or more specifically, upon yield. For example, the Wells and Fox [21] target levels of reserve stocks were based upon an analysis of U.S. crop yield variations during a 50-year period. Gustafson (see section III) also included yield as the only stochastic variable in his model.

Waugh [B] in his study of domestic production since 1927 of major crops, showed that good years tended to be grouped together and poor crop years tended to be grouped. Reserve stocks would need to be larger under these circumstances than if the same good and poor crop years were randomly distributed over time. Waugh also found that when one crop has a poor year, other crops tend to have poor years as well, reducing the possibility of reserves substitution across crops.

Bailey, et al [1] observed that shortfalls in U.S. crop production were fewer but of greater magnitude than the above average crops.

As foreign demand for grains and oilseeds grew, research emphasis also shifted to the role of export demand in determining the size of reserve stocks. Both Bailey [I] and Waugh [B] analyzed the possibility of one country's shortage being offset by another's surplus in a given year. Waugh analyzed intercountry correlations in crop production and found that 23 of 36 correlations were positive indicating that when one country had a short crop, many others were also short. Thus sometimes shortages in individual countries add up to global shortages rather than being offset by other countries' surplus. Analysis reported by Bailey substantiated these conclusions.

McMinimy and Kutish [9] thought there was considerable substitutability among grains in consumption so that the reserve could be specified as (a) small reserves of each type of grain, and (b) bulk of the reserve in the form of "total grain" or a combined food and feed grain. They pointed out that Europe fed from 20-30 percent of its wheat to livestock while in India sorghums were successfully substituted for wheat, and wheat for rice. Thus a smaller total reserve might suffice than if the objective were to maintain separate reserves for each grain.

Mackie [6] concluded after examining trading trends for major wheat importing and exporting countries, that the major factors affecting world wheat supply and demand was the level of North American stocks (Canada and U.S.) and fluctuations of supplies in the Central Plan countries. He found that 93 percent of the deviation about the trend in wheat imports between 1963 and 1974 was accounted for by USSR, China and Eastern Europe, while 92 percent of the deviation about the trend in wheat exports was caused by the U.S. and Canada. Most other importers and exporters exhibited relatively stable trends.

Discount Rate and Risk

The discount rate is an important variable in the analysis of reserve stocks when future returns from those stocks are evaluated. Assume the objective to be evaluated in a stocks model is to maximize present value of future returns. At what rate should future returns be discounted to the present? As the discount rate goes up the present value of future returns from reserve stocks declines and consequently the quantity of reserve stocks decreases.

The discount rate also plays a role in determining who holds stocks. Waugh [20] suggests private industry would store less than desired by society because industry would charge a significantly larger discount rate. Thus government would need to hold stocks as well, or subsidize private industry to hold additional stocks.

One reason for a higher discount rate by private firms is the risk involved in their holding stocks longer than one year. Methods are not now available or customary for hedging against this risk. It is suggested [16] that two ways private trade could hedge in the future would be (a) to develop a 2-3 year futures contract market, and (b) to enter into longer-term contracts with domestic and foreign buyers.

Storage Cost

Little is mentioned in the stocks literature on storage costs except to point out that with higher costs less will be stored. Most studies charge a fixed storage cost per unit stored. For example, Bailey [1, p. 9] charged $5 per ton or about 15 cents per bushel for one year's storage in order to estimate storage costs of various levels of reserve stocks.

Costs of reserve stocks storage were discussed by the Council for Agricultural Science and Technology [14]. Their main points were:

1. Storage costs are generally lower in the U.S. than in importing countries.
2. Cost analysis should account for any price depressing effect of reserves on the market.
3. Cost analysis should also show the reduction in land diversion costs foregone.
4. Recent examples of average storage costs:

			10% interest	UGSA rate*	Total
Wheat	- market	4.50	.45	.15	.60
	- target	2.05	.21	.15	.36
	- loan	1.37	.14	.15	.29
Corn	- market	2.50	.25	.15	.40
	- target	1.38	.14	.15	.29
	- loan	1.10	.11	.15	.26

*Uniform Grain Storage Agreement

Evaluation of Objective Functions

The evaluation of the objective function and resulting storage rule furnishes policymakers and other interested parties with information concerning how the objective and storage rule(s) if adopted will effect the economy. The researcher should provide some criteria for evaluation of both benefits and costs of the program analyzed in order for his research to be useful to policymakers. This topic is discussed more fully in the following sections.

III. Three Empirical Models

Supply and demand have changed considerably since the 1952 Wells and Fox study when yield was the only major stochastic variable that needed analysis. The later Waugh analysis included variances in yield, acreage and foreign demand but the linkage among these variables and the suggested target levels were primarily subjective. The three studies whose review follows, each provide a formal model linking supply and demand and storage rules. They also provide a framework based upon economic theory, that can be used to compare alternative storage rules. The discussion focuses on how each author treated the four basic components of stock analysis as previously outlined.

The Gustafson Model Study: 1958

Objective. Gustafson [4] chose to derive a storage rule that would maximize the sum of discounted expected net gains to society from consuming grain over time. Because of variable production over time, storage between production periods would be needed. He defined net gain in any year resulting from storage as the total social value of grain utilized under the storage program minus the cost of storage. Gustafson used the area under the demand curve for the commodity under consideration as the measure of total social gain in one time period. The methodology of how the rule is obtained is discussed after the remaining components of the model are presented.

Market Conditions. Gustafson utilized a linear demand relation where price equals a constant minus a slope coefficient multiplied by the quantity of grain utilized. The price level of all other goods was assumed constant and this demand function was assumed to be fixed over time.

Furthermore, the demand for feed grains was assumed to be completely domestic demand (i.e., export demand was assumed to be zero).

Supply of feed grains was assumed to be a functional relationship between a constant acres planted and yield which was assumed to be a random variable with a known distribution. The assumption of constant planted acres was not too unrealistic during the 1950's. The role of government in Gustafson's analysis was restricted to that of determination of the level of carryout for feed grains.

<u>Storage Rule</u>. Gustafson defined the storage rule as the unique function Θ which satisfies the following equation.

$$V = \left(\frac{1}{1+r}\right) \int_{0}^{\infty} P[C + X - \Theta(C + X)]\, f(X)dX - \gamma^{1}(C)$$

where V = total expected social value over time discounted to the present,

$\frac{1}{1+r}$ = the discount rate,

r = the interest rate,

P = the demand function for feed grains,

C = the carryover of feed grains from the previous period,

X = total production,

$f(X)$ = the probability distribution function of production,

γ^{1} = the marginal cost of storage.

The storage function Θ then is simply a function of total available supply. The function Θ is found by employing dynamic programming, since the above equation must be satisfied by the storage function Θ for all years in the planning horison. Figure 1 presents one such storage rule derived using the following assumptions.

Since a constant acres planted was assumed, aggregate demand and supply were reduced to demand and supply on a per acre basis.

Demand: $P = \$6.50 - \$0.167(Y)$ Y = bushels per acre

Supply: μ = 30 bushels per acre σ = 3 bushels per acre

Cost of Storage: $0.10 per bushel

Interest Rate: 5%

Figure 1 shows the relationship between total supply (horizontal axis) and carryout (vertical axis). The solid line is a graph of the optimal storage rule Θ. If total supply fell below the equivalent of 30 bushels yield per acre (the expected yield) no stocks would be carried over to next year. If supply were equivalent to yields above 30 bushels, the carryout stock would increase as shown. Remember, this study used data prior to the early 1950's.

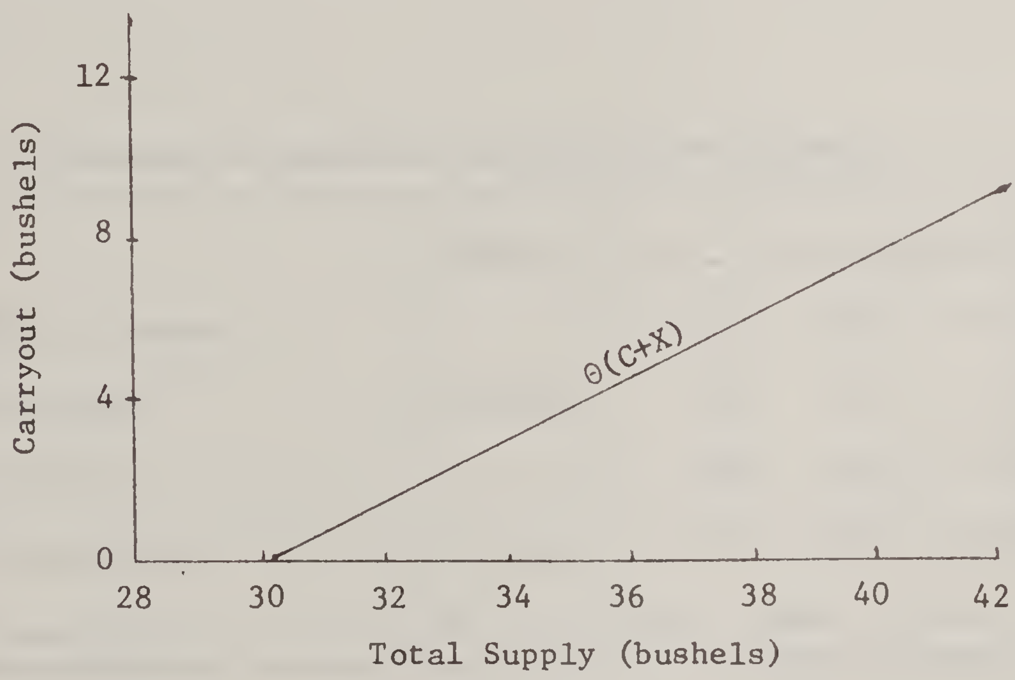

Figure 1.
Optimal Carryover Bushels Per Acre for Feed Grains

In deriving his storage rules, Gustafson assumed constant marginal cost of storage. Although the selection of the discount rate was somewhat arbitrary, prevailing rates were used.

Evaluation of Objective Function. Gustafson derived storage rules for only one objective function. Therefore evaluation or comparison of alternative objectives could not be provided. Gustafson did, however, perform a sensitivity analysis on his results. Table 1 summarizes this sensitivity analysis and illustrates the effect of changes in the elasticity of demand, storage cost, and yield variability on optimal carryover for feed grains (corn, oats and barley in corn equivalent) with an assumed 140 million acres planted to feed grains. Table 2 indicates that optimal carryover is sensitive to changes in demand elasticity, yield variability (supply), the cost of storage and the discount rate.

Table 2. Alternative carryover levels for feed grains.

	Unit	1	2	3	4	5
Elasticity of demand		-.5	-.5	-.3	-.5	-.5
Cost of storage	Dol./bu.	.10	.04	.04	.04	.10
Discount rate		.02	.02	.02	.02	.05
Yield variability	Bu./acre	3.03	3.03	3.03	5.05	3.03
Optimal carryover	Mil. bu.	270	396	578	620	242

Gustafson illustrated mathematically how his basic model could be modified to include the effects of foreign demand and supply. Gustafson shows that although he specifies the model to maximize gain to the general public, the method of solution can be modified to maximize gain to farmers or any other sector. He also points out that the model is specified "... in terms of net gains or losses arising from changes in quantities stored or utilized rather than in terms of price stabilization", but "the carryover rules ... can easily be converted to equivalent price-setting rules."

The assumptions of static demand and a constant acreage planted to feed grains restrict the usefullness of his model, but all other basic economic variables related to carryover are included in the model. He also pointed out two major implications from his results. The first is that the quantity of grain that would be stored by private firms maximizing expected net revenues in a competitive market would be the same as the quantity of grain stored by a government agency maximizing the sum of discounted expected social gains. The second implication is that if the government operates the storage program directly, given Gustafson's assumptions, the expected cost to the government of operating an optimal program is zero.

The Gislason Model 1961

Objectives. Gislason [3] derived storage rules for two alternative objectives. The first objective was to derive a storage rule for the private sector using profit maximization as the objective. The second objective was to derive a storage rule for the public sector using profit maximization of net returns from an ever normal granery model as the criterion for optimization.

Storage Rule for the Private Sector

The storage rule for the private sector model results from assuming firms in the private sector compare the price they expect to receive for the commodity in the next period with the price in the current period. If the difference between the two prices is greater than the cost of storage then storage is undertaken and if the difference is less than the cost of storage then no grain is stored. The quantity stored is determined as follows.

Net returns from storage can be written as

$$P_1 - P_0 = C \tag{1}$$

where P_1 = price next year,

P_0 = current year,

C = cost of storage.

Gislason assumed a perfectly competitive market with aggregate profits summing to zero. Thus equation (1) results. He further assumed a linear demand function of the form:

$$P = a - bQ$$

Therefore by subtracting the quantity to be stored (S) from current supply (X_0) the demand function for the current year becomes:

(2) $$P_0 = a - b(X_0 - S)$$

Let $\hat{H}$ be the expected harvest next year. Assuming all grain available next year is consumed, the demand for the next year becomes:

(3) $$P_1 = a - b(\hat{H} + S)$$

Now substituting equations (2) and (3) into (1) and solving for S:

$$S = 1/2[X_0 - \hat{H} - \frac{C}{b}]$$

Where the quantity to be stored is a function of total available supply (X_0), expected harvest next year ($\hat{H}$), the cost of storage (C) and the slope of the demand curve (b).

Market Conditions. In the private sector model Gislason assumed a perfectly competitive market with a further restrictive assumption that aggregate profits for the industry as a whole sum to zero. This assumption of zero aggregate profits allowed him to ignore the effect of discounting. Therefore the Gustafson model, discussed previously with a discount rate of zero, is approximately equivalent to Gislason's private sector storage model. Gislason employed a linear demand function which was assumed to be stationary over time with the price levels of all other goods held constant. Gislason also assumed an isolated economy (i.e., no foreign demand).

Supply was assumed to be a constant known with certainty by the private sector.

Evaluation of Results

Gislason derived a theoretical storage model for corn using an assumed price elasticity of demand of -.65 for the period 1926-40, total yearly production of 2,367 million bushels, and an average price of 72¢ per bushel, and a constant storage cost of 10¢ per bushel. He then applied his rule to the production that occurred during the period 1926-37.

Table 3 compares actual carryover with the optimum carryout obtained by using the private sector storage rule. Gislason did not perform a sensitivity analysis although he did compare the carryout obtained by employing his private sector model with actual carryout of corn. These comparisons are shown in table 3.

Storage Rule for the Ever Normal Grainery Model.

Gislason used the storage function given in equation (1) to equate the marginal cost of storage with the marginal returns to storage.

$$S = g(X - Q) \tag{1}$$

where S = quantity to be stored,

X = total quantity of grain available,

g = proportion of the total quantity of available grain in excess of Q (a constant) that is held as carryover stocks.

Gislason shows that marginal cost is equated with marginal returns when:

$$b \sqrt{V_0}\, \Delta V_C = C\, \Delta ES \tag{2}$$

where b = the slope of the demand curve,

V_0 = variance of crop sizes,

ΔV_C = the change in the variance of consumption with respect to a change in either g or Q,

C = cost of storing a bushel of grain for 1 year,

ΔES = the change in the average quantity stored when either g or Q changes.

Table 3. Actual carryover for corn compared with optimal carryover for the private and public sectors.

	Adjusted actual carryover	Model Results	
		Private sector model	Public sector model
	(Million bushels)		
1926	128	89	190
1927	21	93	196
1928	62	56	137
1929	63	11	68
1930	114	0	0
1931	179	48	126
1932	283	278	484
1933	273	70	159
1934	16	0	0
1935	106	0	0
1936	34	0	0
1937	262	36	106

Market Conditions. Gislason assumed a static linear demand function solely determined in the domestic market. Supply was assumed to be a random variable where yields were assumed to be normally distributed multiplied by a constant planted acres. The only government intervention was that attributable to operation of the storage rule. The marginal cost of storage was assumed to be a constant.

Monte Carlo Evaluation of Results. The operation of the rule was simulated several hundred times for various values of the parameters g and Q of the storage rule. The storage rule derived for corn for the period 1926-1937 is given in equation (3).

$$S = .78(X - 2,582,000,000) \tag{3}$$

A comparison of actual carryout of corn with that obtained by employing the storage rule is presented in table 3. The Gislason analysis agrees with that of Waugh in that the private sector will store less grain than the public sector. However when he expanded his models to include world demand he found that the private sector would store more grain than would the public. This result was probably due to the non-stochastic nature of his assumed foreign demand function. The static linear demand and constant planted acres assumptions do abstract the models significantly. The results are consistent with Waugh's argument that the private sector will store less than the public sector under similar conditions.

The Tweeten Model: 1971

Tweeten [17] used an aggregate U.S. wheat simulation model to evaluate the effects of three alternative storage rules on the mean and variance of twelve variables including (a) prices, (b) receipts, (c) net farm income from wheat, (d) production, (e) stocks, and (f) net social cost (defined as the absolute difference between the area under the demand curve and the area under the supply curve bounded by the given quantity utilized and the equilibrium quantity). The model was designed to apply to the 1970 structure of the wheat industry with an equilibrium starting point of 1.6 billion bushels supply-demand, 62 million acres planted, a 25 bushel yield and a farm price of $1.20 per bushel.

Market Conditions

Demand consisted of two components; domestic (a function of price) and export (a function of price, quantity exported last year and a random disturbance). The disturbance term was uniformly distributed between +200 and -200 million bushels.

Production was the product of acreage and yield. Yield was a random variable with the distribution empirically estimated. Acreage was either determined by the market or determined by policy decision.

market determined acreage = .155 (last year's price)
+ .7 (last year's acreage)

policy determined acreage = (demand plus desired stocks change)
÷ (yield)

Model I: Model I contained no explicit storage rule. It approximated a free market situation. Demand for stocks was defined as a component of total demand and had the following form:

$$QS_t = 70 \qquad P > 200$$

$$QS_t = 895 - 4.125\ P_t \qquad P \leq 200$$

where: QS_t = carryout stocks (million bushel),
P = price (cents),

Supply was either market determined or determined by policy decision using three alternative levels of carryout: 200, 400 or 600 million bushels.

Model II: A storage rule was defined where stocks were used to achieve domestic price stability and meet emergency needs. Upper and lower bounds on price were set and stocks were decreased if market price rose above the upper bound and stocks were increased if price fell below the lower bound.

<u>Model III</u>: The storage rule used in Model III closely resembled that obtained by Gustafson. However, instead of the objective being to maximize net social gain as did Gustafson, Tweeten minimized net social loss. Dynamic programming was used to obtain the storage rule which was then used in the simulator. The storage rule was:

$$QS_t = \theta(S_t - 1{,}550)$$

where: QS_t = carryout stocks (million bushel),

S_t = supply (million bushel).

The optimum value for θ was .85 but values from .70 and 1.0 were also used in Model III.

<u>Results</u>

Tweeten did not provide any historical comparisons of his model results with actual carryover. However, his results seem reasonable given his assumptions and time period. Carryout varied (depending on parameter assumptions and model chosen) from a low carryout of 116 million bushels to a high carryout of over 700 million bushels and wheat market prices ranged from $0.77 to $1.90 per bushel.

The major conclusion shown by Tweeten is that there is no best or optimal policy for reserve stocks. The optimal policy depends upon the objective(s) being sought. Thus the mean, variance and range of several variables are shown in the research report for each solution. Other conclusions are:

1. Social cost is relatively small for most storage models studied.
2. Government stock management operations work best when accompanied with Government acreage controls.
3. The success of Model II (using upper and lower bounds on price to determine stocks purchase or sale) depends upon the ability to accurately estimate equilibrium price, while Model III needs accurate equilibrium

quantity estimates to provide a successful storage rule. The authors conclude that given their subjective evaluation, storage rules based on Model II are superior to those from Model III.

4. In general, a target carryover of about 400 million bushels of wheat was recommended plus pipeline stocks of an additional 50-100 million bushels.

IV. Conclusions

Major structural change has taken place since reserve stock levels were estimated by Wells and Fox, Waugh and others. The empirical studies reviewed give valuable insights into model building but their results are also out of date because of the rapid structural change taking place in recent years. Up-to-date estimates are needed for policy analysis, so additional research is needed. New models can incorporate the strengths of the old and include changes relevant to the changing structure of markets and institutions.

The conclusions section presents a short critique of how the reviewed literature treated the four major components of grain stocks analysis, as presented in the preceding sections. Suggestions are made about certain aspects of these components which should be expanded in future research on grain stocks.

Objectives and Storage Rules

Three general conclusions can be drawn from the literature about objectives and storage rules. First, there is no one optimal stocks policy. Many objectives are listed in the literature. Each may require unique storage rules, and each storage rule may result in a different level of reserve stocks, given the same set of economic conditions. The three empirical

studies reviewed in this paper derived storage rules for six objectives. Those objectives were 1) maximize expected net social gain (Gustafson), 2) reduce price variability (Tweeten), 3) minimize expected net social loss (Tweeten), 4) maintain storage at alternative specified target carryout levels (Tweeten), 5) maximize profit from storing grain for one time period only for the private sector (Gislason), and 6) maximize expected returns to storage for the public sector (Gislason). Each gave different results.

Second, since different objectives yield different results, future research should measure the impact of alternative storage rules on a variety of variables such as the level and dispersion of farm income, prices, stock levels, costs, etc. This comparison is a valuable contribution of Tweeten's study.

Third, storage rules which are concerned with objectives which maximize social welfare need to be reviewed more thoroughly. The question of how to measure social welare has not been fully answered in the literature. Therefore, an indepth review of this question needs to be performed before analyzing storage rules which use social welfare as a criterion.

Market Conditions

Demand

In future analyses three aspects of the demand portion of these previous studies need to be examined. First, export demand was incorporated into their analyses either indirectly or not at all. Foreign demand has become an increasingly important component of aggregate demand for U.S. agricultural commodities. The extreme volatility of foreign demand as well as changing exchange rates have become the rule rather than the exception, thus they need to be included in future studies of grain reserves.

Second, the short-run demand functions were static over time. Recent experience suggests that the dynamic nature of demand should be considered in order to evaluate the stability over time of alternative grain reserve proposals.

Third, the authors analyzed grain reserve policies for one commodity or one group of commodities, whereas McMinimy and others suggested that there was substantial substitutability in demand for the various food and feed grains. Simultaneous analysis of both food and feed grains would seem appropriate in the future.

Supply

An important question in future analysis is, "what combination of land diversion and stocks management would be optimal for certain objectives?" Tweeten's model contains government acreage management and his results show the two policy instruments can be used effectively together.

All studies treated yield as a random variable but only Tweeten treated supply as a function of the commodity's own price. An attempt should be made in future analyses to deal with variations in acreage planted.

Private vs Public Control

A major issue needing evaluation in future stocks models is, "given the various objectives for having reserve stocks, does it make any difference who controls the stocks?" What does economic theory have to say on this issue? Does public control lead to greater social well-being? If there were no public reserve stocks, would the private sector hold a socially desirable level of stocks? Can public control be separated from political manipulation? Some of these questions are able to be researched and should be addressed in future reserve stocks models.

Evaluation of Results

The evaluation of the effects of storage rules on key economic indicators is one of the more important aspects of any research on grain reserve programs. Some indicators that need to be reported are 1) the cost of the program to the government, 2) the mean and variances of (a) prices, (b) income, and (c) production, and 3) exports. Without this information policymakers or economists cannot effectively evaluate two or more alternative programs. Once a program has been adopted, these indicators are needed so that administrators can measure the progress towards achievement of the program objectives.

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